Manitoba
Environment
and Workplace
Safety and Health

A STUDY OF FOREST VEGETATION IN THE FLIN FLON AREA FOR ATMOSPHERIC EMISSION EFFECTS FROM THE H.B.M.&S. SMELTER

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ABSTRACT

Forest vegetation from a network of 8 study sites in the Flin Flon area was evaluated to determine the effects of atmospheric emissions from the H.B.M.&S. smelting complex. The forest community was sampled by two complementary methods: 1/10 hectare circular macroplots for the tree and high shrub layer, and 1 metre square microplots for the lower shrub-herb/cryptogam layer. All species within each study site were inventoried for presence, abundance and size for benchmaking purposes in 1978 and re-evaluated in 1983.

Tree and shrub data are summarized and discussed in the text by study site for both 1978 and 1983. The 5 year evaluation of understory species is presented by distribution and species diversity based on an association index value of frequency and cover.

Study sites located in a transect south of the smelter stack showed symptoms of stress with declining vegetation in evidence 5 years after benchmarking. In particular trees at site 5, 5.8 km S.S.E., had a higher tree mortality and a reduced total living basal area. In addition, sites closest to the smelter were found to have a decline in shrub and understory layers.

The abundance of mosses and lichens in the study network was lowest near the smelter and increased at farther plots. Further monitoring is required to quantify the impacts and to better comprehend the documented changes in species diversity as well as to establish cause and effect relationships.

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INTRODUCTION

In 1977 the Environmental Management Division of the Province of Manitoba in co-operation with the Canadian Forestry Service of Environment Canada entered into a joint study of air contaminant effects on forest ecosystems surrounding northern mining smelters in the province. An inventory and evaluation of the forest communities in the vicinity of these smelting centres was a major component of this forest study. The inventory was designed to determine and document the conditions of forest vegetation and to establish a benchmark from which long term biological monitoring could be carried out.

In Flin Flon the Hudson Bay Mining and Smelting Company Limited (H.B.M.&S.) has operated a copper-zinc smelter for over half a century. Typical of a non-ferrous smelting complex, emissions of sulphur dioxide and heavy metal particulates are released to the atmosphere in considerable quantity. The major source of air borne emissions from the H.B.M.&S. complex is the 251 metre (825 foot) stack.

The H.B.M.&S. complex operates under the Manitoba Clean Environment Commission Ordinary Licence No. 195 issued on January 8, 1973 and amended by Order No. 18/72 of the Municipal Board. Pursuant to its efforts to preserve the quality of the environment, the Environmental Management Division sought to increase its baseline information specific to the forest ecosystem of the Flin Flon area. It was anticipated that such information could be

used to assist in the administration of the Clean Environment Act, as it applied to the control of atmospheric emissions from the smelting industry.

This report presented herein provides an outline of the forest inventory component and a 5 year evaluation of the forest vegetation within the scope of the federal/provincial forest study at Flin Flon, Manitoba.

STUDY OBJECTIVES

This study was designed to identify and document the presence, diversity and ecological state of forest vegetation from 8 selected sites in the vicinity of the H.B.M.&S. smelting complex at Flin Flon, Manitoba.

Further to this, the study was designed to establish benchmark data for carrying out biological monitoring of the forest vegetation at 5 year intervals to determine if environmental impact is occurring as a result of air borne contaminants of sulphur dioxide and heavy metals.

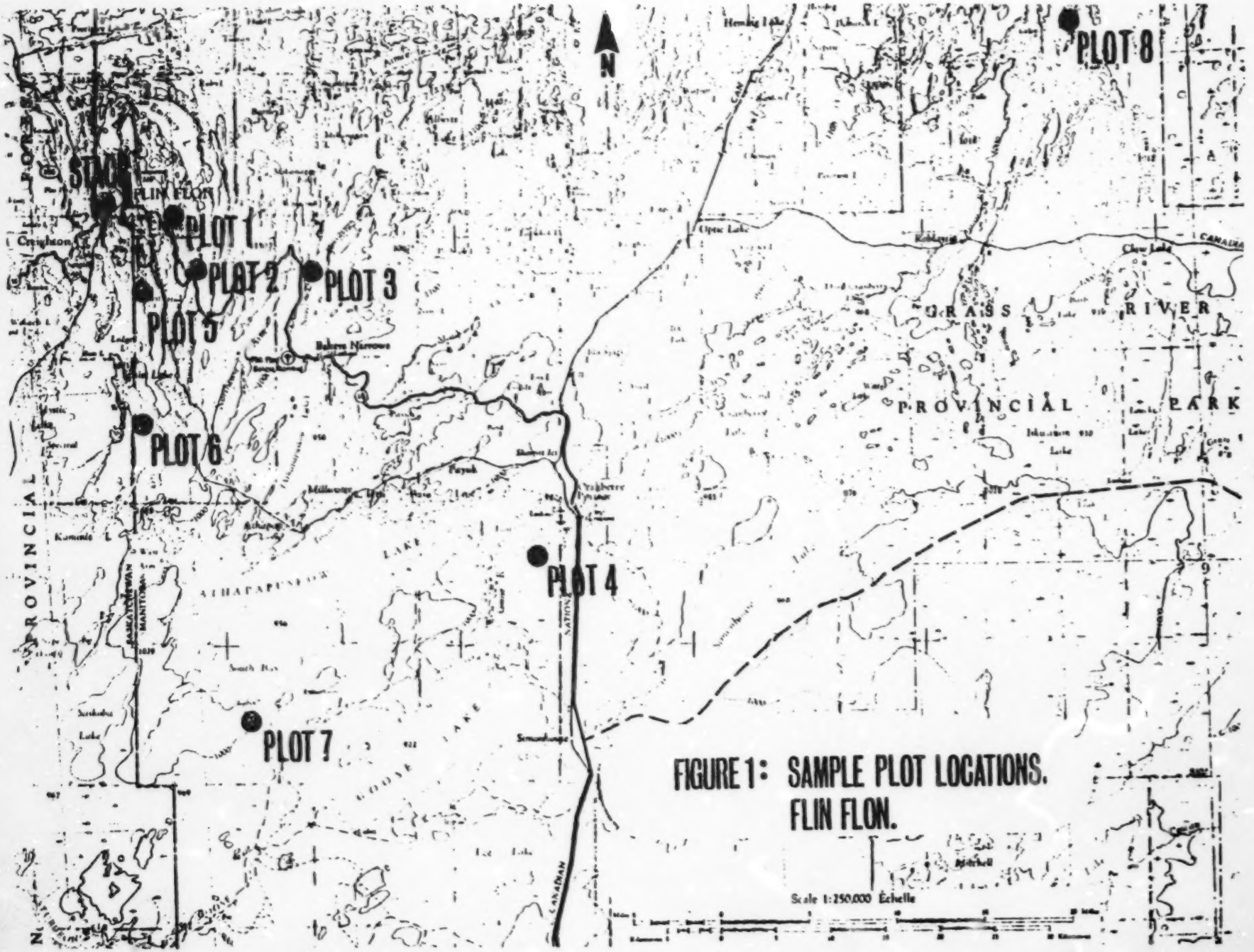

FIGURE 1: SAMPLE PLOT LOCATIONS. FLIN FLON.

TABLE 1: STUDY PLOT LOCATIONS, FLIN FLON

Plot Number	Direction From Stack	Distance From Stack (km)	Latitude	Longitude	Legal Desc.
1	E.S.E.	5.1	54°45'36"	101°48'48"	Sec 4-67-29
2	S.E.	8.9	54°43'24"	101°46'30"	Sec 29-66-29
3	E.S.E.	15.5	54°43'24"	101°39'48"	Sec 20-66-28
4	S.E.	38.1	54°33'00"	101°26'06"	Sec 23-64-27
5	S.S.E.	5.8	54°43'30"	101°50'18"	Sec 30-66-29
6	S.	14.6	54°38'18"	101°50'48"	Sec 18-64-29
7	S.	35.7	54°27'36"	101°43'48"	Sec 23-63-29
8	E.	68.2	54°52'18"	100°50'48"	Sec 11-68-23

STUDY METHODS AND PROCEDURES

STUDY SITE SELECTION:

A network of 8 study sites or study plots was established in the Flin Flon area in 1978. These sites were selected following a review of meterological data, patterns of pollutant dispersal, forest inventory records and documented areas of forest decline. The sites were located along 2 transects, one to the southeast and one to the south, at increasing distances away from the smelter, an exception being the control east of the smelter.

Figure 1 is a map of the study site locations and Table 1 provides the physical description of each location. Sites 1 to 4 were located along the southeastern transect at distances of 5.1, 8.9, 15.5 and 38.1 km and sites 5 to 7 were located in the southern transect at distances of 5.8, 14.6 and 35.7 km from the smelter. The control site, site #8, was established at Elbow Lake, 68.2 km east of the smelter.

A review of forest inventory records and maps for the Flin Flon area indicated that the most productive and frequent forest stands suitable for benchmark study were mixed coniferous-deciduous. Study sites were established in mixed forest stands with an attempt to include where possible elements of Pinus banksiana Lamb. (Jack Pine), Picea glauca (Moench) Voss (White Spruce), Populus tremuloides Michx. (Trembling Aspen), and Populus balsamifera L. (Balsam poplar). An attempt was also made to select sites of similar stand composition structure, age, aspect, understory and soil characteristics where possible.

VEGETATION INVENTORY

The forest vegetation of the 8 study sites was stratified into the 3 major layers of: tree-shrub, low shrub-herbs and cryptogam. Two complementary sampling networks were designed to satisfy this objective, one for the larger tree and high shrub and the second for the lower shrub-herb/cryptogam layers.

TREE AND HIGH SHRUB

A circular macroplot of 1/10 hectare size was established in each of the eight study sites to describe the plant communities present. The vegetation found within each macroplot was stratified into the 2 major layers of tree cover and high shrubs. Shrubs were defined as woody plants taller than 50 cm.

All trees within each macroplot were identified and estimates of physical condition, abundance and size were taken. Each tree was tagged with a number, measured for diameter at breast height and its location mapped within the macroplot. Three representative trees from each study site were selected for age determinations and height measurements.

All shrubs within each macroplot were identified, evaluated for physical condition, abundance and size to provide details of species composition and distribution. Each shrub clone in the macroplot was identified, it's location within the macroplot was mapped, and the number of stems were counted. The density of shrub clones in each macroplot was used as a measure of abundance and measurements of height and crown width were taken for calculations of cover.

LOW SHRUB HERB

A series of six one-metre square microplots spaced at ten metre intervals were established along a linear transect away from the southern-most edge of the larger macroplot. On each microplot, the vascular community was further stratified into the following components:

LOW SHRUBS: woody plants less than 50 cm high with an indefinite number of stems arising from a single rootstock

TALL HERB: non-woody species between 15 to 50 cm in height

LOW HERB: non-woody species less than 15 cm in height

CRYPTOGAMS: the common ground moss, liverwort, lichen and fern layer.

The above strata were sampled for species composition, density, frequency and percent cover in each of the six macroplots per study site. Individual specie members were examined for foliar condition concurrently with sampling procedures. Only the more common species of cryptogams which were easily recognized in the field were included in the vegetation description. Due to the high degree of specialization required, a detailed investigation of these groups was not carried out.

For the purpose of this study, an individual plant was defined as one being rooted within the quadrat and having a distinct and single root origin. This system was difficult to apply in the case of species in the Ericaceae family where creeping stems were often rooted at the nodes. In such cases, a decision was made to count each rooted segment as an individual. The cover of each species

was also difficult to determine accurately with a one metre square quadrat. To increase the accuracy of cover estimates the large quadrat was subdivided into four equal units and measurements of density and cover were taken for each 1/4 quadrat and then totalled. In each plot, all microplots were photographed to provide a permanent record of vegetation for future reference.

The vegetation data collected from each macroplot were to calculate density, relative density, dominance, relative dominance, frequency and relative frequency for each species in the shrub/herb stratum of each study plot. These data were used to calculate an association table of understory species for comparison between study sites.

The formulae used to calculate the above values are listed below:

$$\text{Density} = \frac{\text{Number of individuals}}{\text{Area sampled}}$$

$$\text{Relative Density} = \frac{\text{Density for a species}}{\text{Total density for all species}} \times 100$$

$$\text{Dominance} = \frac{\text{Total basal area for aerial coverage values}}{\text{Area sampled}}$$

$$\text{Relative Dominance} = \frac{\text{Dominance for a species}}{\text{Total dominance for all species}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of plots in which species occurs}}{\text{Total number of plots sampled}}$$

$$\text{Relative Frequency} = \frac{\text{Frequency value for a species}}{\text{Total of frequency values for all species}} \times 100$$

$$\text{Association Table} = \frac{\text{\% Frequency + \% Cover}}{2}$$

RESULTS AND DISCUSSION

TREE STRATUM

A summary of inventory data for tree species from both 1978 and 1983 is found in Table 2. Physical measurements of diameter, height, age and percent (%) mortality are presented in addition to basal area. To facilitate the discussion, the results are presented in order by transect.

The southeastern transect is composed of sites 1, 2, 3 and 4. Site 1 has the largest number of tree species present (6), although their height and diameter are generally smaller. Thus the total living basal area of site 1 is smaller than other sites sampled, however at site 1, there has been a consistent increase in basal area of all species during the past 5 years.

Sites 2, 3, and 4 are also located along the southeast transect at distances of 8.9, 15.5 and 38.1 km respectively. The tree data for diameter, height and % mortality of these sites does not show any radical changes over the 5 year interval. The basal area data shows a progressive increase per site with increasing distance away from the smelter in 1978 and again in 1983; site 2 was an exception in that basal area decreased in 1983. It is of note that this decrease in basal area was substantially larger than the increases experienced at the other sites.

Sites 5, 6, and 7 are located along the southern transect at distances from the smelter of 5.8, 14.6, and 35.7 km respectively. There were 4 tree species present at site 7 and 3 species at sites 5 and 6. In general, physical characteristics of size were similar

Table 2: SUMMARY OF DATA ON TREE SPECIES FROM BIOMONITORING SITES IN FLIN FLON

Plot No	Tree Species	Mean Diameter(cm) 1978	Mean Diameter(cm) 1983	Mean Height(m) 1978	Mean Height(m) 1983	Mean Age(yrs) 1978	Mean Age(yrs) 1983	% Mortality 1978	% Mortality 1983	Basal Area Plot (cm^2) 1978	Basal Area Plot (cm^2) 1983	Total Living Basal Area (cm^2) 1978	Total Living Basal Area (cm^2) 1983
1	Picea mariana	10.84	11.78	10.97	-	65.0	-	-	14.29	693.97	709.65		
	Picea glauca	8.03	8.76	11.23	11.89	65.0	70.0	-	-	978.39	1165.55		
	Betula papyrifera	6.18	6.30	-	-	-	-	28.57	28.57	169.25	175.97	2351.99	2609.03
	Larix laricina	6.90	7.24	-	-	-	-	-	-	341.30	373.76		
	Alnus spp.	4.70	5.20	-	-	-	-	-	-	17.34	21.24		
	Pinus banksiana	13.90	14.40	-	-	-	-	-	-	151.74	162.86		
2	Picea mariana	15.80	16.40				-	50.00	50.00	196.07	211.24		
	Picea glauca	21.91	22.50	18.59	18.90	75.0	80.0	61.90	76.19	3162.86	2696.04	4655.51	3816.78
	Betula papyrifera	9.20	9.40	-	-	-	-	-	-	66.48	69.40		
	Larix laricina	14.1	14.52	-	-	-	-	-	20.00	830.10	840.10		
3	Picea mariana	23.55	25.05	-	-	-	-	60.00	60.00	871.65	937.10		
	Picea glauca	14.72	16.70	15.85	17.37	92.0	97.0	-	12.5	1674.93	1809.62	5216.81	5656.03
	Populus balsamifera	23.38	24.12	-	-	-	-	-	-	2723.23	2889.31		
4	Picea mariana	14.46	14.38	18.89	19.51	78.0	83.0	25.00	28.13	3916.40	3902.55		
	Picea glauca	16.60	19.10	16.46	16.77	86.0	91.0	-	-	817.13	867.87	4043.66	4165.60
	Larix laricina	16.18	16.68	-	-	-	-	14.28	14.28	1310.13	1395.18		
5	Picea mariana	-	-	-	-	-	-	100.00	100.00	-	-		
	Picea glauca	10.15	10.58	20.12	20.73	55.0	60.0	-	9.52	2433.78	2618.52	4609.63	4172.83
	Larix laricina	6.90	7.03	-	-	-	-	-	25.00	150.74	126.24		
	Populus balsamifera	15.03	15.19	-	-	-	-	-	10.00	2025.11	1478.07		
6	Picea mariana	8.33	9.24	-	-	-	-	10.00	10.00	624.14	748.58		
	Picea glauca	36.00	36.90	19.05	20.42	76.0	81.0	33.33	33.33	2025.03	2139.82	4000.41	3729.73
	Pinus banksiana	-	-	-	-	-	-	100.00	100.00	-	-		
	Populus balsamifera	14.43	15.03	-	-	-	-	-	50.00	1751.24	841.33		
7	Picea mariana	11.70	11.90	16.76	17.38	75.0	80.0	80.00	80.00	107.51	111.22		
	Picea glauca	14.45	14.85	17.37	18.29	90.0	95.0	14.48	21.43	2063.52	1918.35	4558.91	4505.45
	Larix laricina	12.66	13.21	-	-	-	-	-	11.11	1163.24	1134.71		
	Pinus banksiana	28.55	28.95	-	-	-	-	-	-	1284.64	1320.77		
8	Picea mariana	12.36	12.57	18.75	19.21	-	-	15.38	15.38	3076.55	3164.27		
	Picea glauca	8.13	8.66	-	-	-	-	-	7.14	917.81	1044.28	5709.18	5840.32
	Larix laricina	10.33	10.70	-	-	-	-	-	-	255.05	274.62		
	Populus balsamifera	14.17	14.46	-		-	-	-	11.11	1459.76	1357.15		

between sites. The youngest trees were found at site 5, yet percent mortality for the 3 tree species found at site 5 increased in 1983. Mortality occurred in Populus balsamifera in site 6 and Picea glauca and Larix laricina at site 7. In 1978 the highest total living basal area for the south transect was found at site 5 however, 5 years later site 5 had experienced the largest decrease in basal area (436.8 cm^2). The basal area also declined over the 5 year period at sites 6 and 7 however, the decrease was greatest at site 5.

The control site, site 8, was comparable to other sites for most parameters measured. Low levels of mortality were recorded for 2 of 3 species after the 5 year period. The total living basal area was the largest of all sites in both 1978 and 1983 and showed an increase over the 5 year period.

SHRUB STRATUM

In Table 3 a summary of inventory data for the high shrub stratum from 1978 and 1983 is presented. Physical measurements as well as relative density and percentage cover are available. The species Alnus was found in all sites except the control site #8 where no shrubs were found; however, presence of other species was variable between sites.

In the southeastern transect both sites 1 and 3 had only Alnus present. In general all physical measurements for shrubs in sites 1, 2, 3, and 4 increased during the 5 year period. The exception was at site 1 where the number of shrubs per site decreased from 18 to 8 and the number of stems per site decreased from 109 to

Table 3: SUMMARY OF DATA ON SHRUB STRATUM FROM BIOMONITORING SITES IN FLIN FLON

Plot No	Shrub Species	Mean Height(m) 1978	Mean Height(m) 1983	Mean Crown Width(m) 1978	Mean Crown Width(m) 1983	Mean # Stems/Shrubs 1978	Mean # Stems/Shrubs 1983	Total Shrubs/Plot 1978	Total Shrubs/Plot 1983	Total Stems/Plot 1978	Total Stems/Plot 1983	Relative Density 1978	Relative Density 1983	% Cover 1978	% Cover 1983
1	Alnus spp.	2.68	2.86	1.30	1.69	6.05	9.75	18	8	109	78	100.0	100.0	21.89	17.95
2	Alnus spp.	2.20	2.60	1.20	1.90	6.50	11.00	2	2	13	22	25.0	25.0	2.26	5.67
	Viburnum trilobum	0.50	0.55	0.30	0.40	2.00	2.00	1	1	2	2	12.5	12.5	0.07	0.13
	Shepherdia canadensis	0.67	0.91	0.55	0.94	3.40	6.40	5	5	17	32	62.5	62.5	1.18	3.47
3	Alnus spp.	2.97	3.99	1.79	1.96	12.90	16.56	10	9	129	149	100.0	100.0	25.16	27.15
4	Alnus spp.	0.91	1.40	0.88	0.85	2.75	5.00	4	2	11	10	40.0	40.0	2.43	1.13
	Cornus stolonifera	0.75	0.90	5.47	0.75	2.00	2.00	2	2	4	4	40.0	40.0	0.34	0.88
	Rosa acicularis	0.65	0.80	0.30	0.30	1.50	2.00	2	1	3	2	20.0	20.0	0.14	0.07
5	Alnus spp.	2.64	4.25	1.96	2.00	1.20	1.50	5	2	6	3	6.45	6.06	15.08	6.28
	Cornus stolonifera	1.04	1.02	0.72	0.44	1.87	1.74	31	23	58	40	74.19	69.70	12.62	3.50
	Prunus virginiana	1.10	1.03	0.60	0.57	2.75	1.67	4	3	11	5	9.68	15.15	1.13	0.77
	Viburnum trilobum	0.65	0.82	0.31	0.48	1.66	2.67	3	3	5	8	9.68	9.09	0.22	0.54
6	Alnus spp.	2.25	3.17	1.72	2.33	14.00	12.67	5	3	70	38	75.0	75.0	11.61	12.79
	Rosa acicularis	0.80	0.60	0.30	0.20	1.00	1.00	1	1	1	1	25.0	25.0	0.07	0.03
7	Alnus spp.	0.79	1.50	1.27	0.80	1.66	4.00	3	1	5	4	50.0	50.0	1.80	0.50
	Rosa acicularis	0.60	0.70	0.30	0.40	2.00	1.00	1	1	2	1	50.0	50.0	0.07	0.13
8		-	-	-	-	-	-	-	-	-	-	-	-	-	-

78. Accordingly in site 1 the percent cover decreased from 23.89 to 17.95 as well.

In the southern transect the shrub stratum was notably disturbed at all sites. Study site 5 had the largest number of shrub species and in general showed the greatest decline in shrub vigour over the 5 year period. In particular the total number of shrubs per plot and total stems per plot were reduced substantially for 3 of the 4 species present. The relative density and percentage cover were reduced accordingly in site 5. Reductions in shrub presence and cover were also found in sites 6 and 7 for both the Alnus and Rosa genera. These results indicate that sites in the southern transect are responding to a stress situation.

UNDERSTORY

The description and documentation of understory species is a labour-intensive task and the interpretation of the raw data is difficult and equally time consuming. To facilitate interpretation, the initial benchmark data were compiled into an association table or table of species diversity based on the percentage frequency and cover for each species by study site. The percentage change in association value between 1978 to 1983 has been calculated and appears in Table 4. Table 5 provides a comparison of the distribution and association values for all understory species between 1978 and 1983.

In Appendix A, the inventory data for 1978 are presented in table format. The association values for 1978 are summarized per study site in Table A-1. The distribution of the vascular understory is found in Table A-2, and the distributions of cryptogams, (moss, liverwort and lichens) is found in Table A-3. For each study site a table of species composition and abundance, including values of density, dominance and frequency, was prepared and is provided in Tables A-4 through A-11.

Similarly, inventory data for 1983 are presented in Appendix B. The 1983 association values are summarized by study site in Table B-1. The distribution of the vascular understory is found in Table B-2 and the distribution of cryptogams is found in Table B-3. A summary of species composition and abundance for each site is found in Tables B-4 through B-11.

DISTRIBUTION - VASCULAR PLANTS:

The distribution of understory vascular plants for 1978 and 1983 is illustrated by Figure 2. It is evident that study site 5 has the largest number of species present in both years, however, a decrease in number is indicated for 1983. The only other site with a decrease in number of species is site 2. Sites 2, 3, 4 and 6 are shown to be very similar in number of species present over the 5 year period and as indicated only site 2 shows a reduction in number. In all cases whether species are increasing or decreasing, the fluctuation is limited to from 1 to 3 species for all sites.

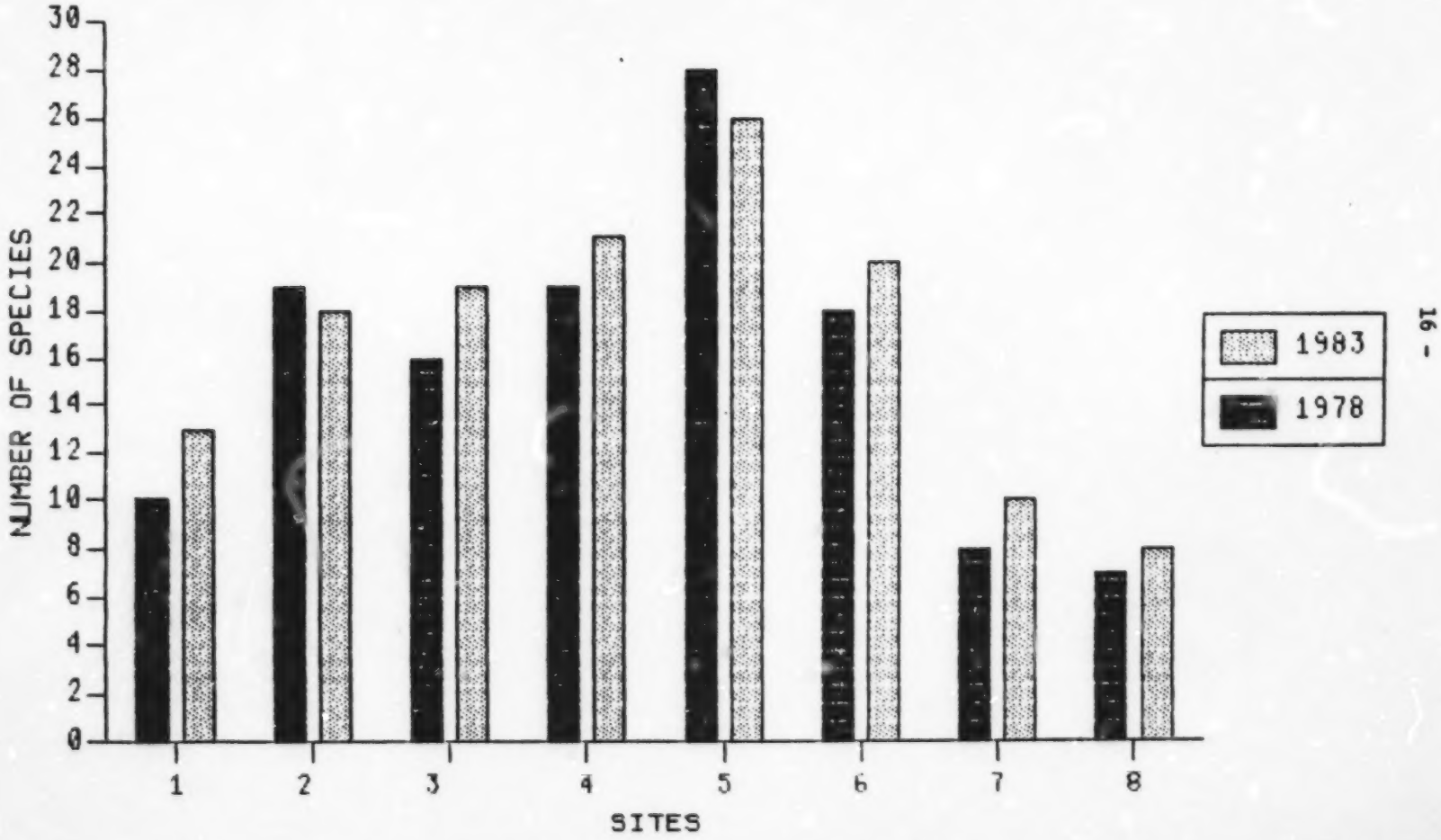

FIGURE 2: UNDERSTORY DISTRIBUTION IN FLIN FLON STUDY SITES

Site 1 shows the largest increase in species, however, the number of species present is notably less than sites 2 to 6. Sites 7 and 8 have the least number of species of all sites sampled. New species were recorded in both sites in 1983.

The understory distribution in general provides an indication of site vigour, however, interpretation is limited. More precise definition is provided by the association data since both frequency and cover are considered.

DISTRIBUTION - CRYPTOGAMS:

The distribution of cryptogams on the sites between 1978 and 1983 is illustrated by Figures 3 and 4. In both the southeastern and southern transects there was a distinct trend found in the moss and lichen cover. In both transects those sites closest to the smelter were found to have fewer species than those at farther distances.

The sites located farthest away from the smelter, sites 4 and 7, were found to have a moss and lichen distribution similar to that found at control site #8. The number of moss species found in 1983 was consistently less than that found in 1978. The number of lichen species found at the 3 sites located farthest away from the smelter, sites 4, 7 and 8 were found to have increased over the five year period. In comparison the number of recorded species remained unchanged at one species for sites 1, 2, 3 and decreased by two species at site 6.

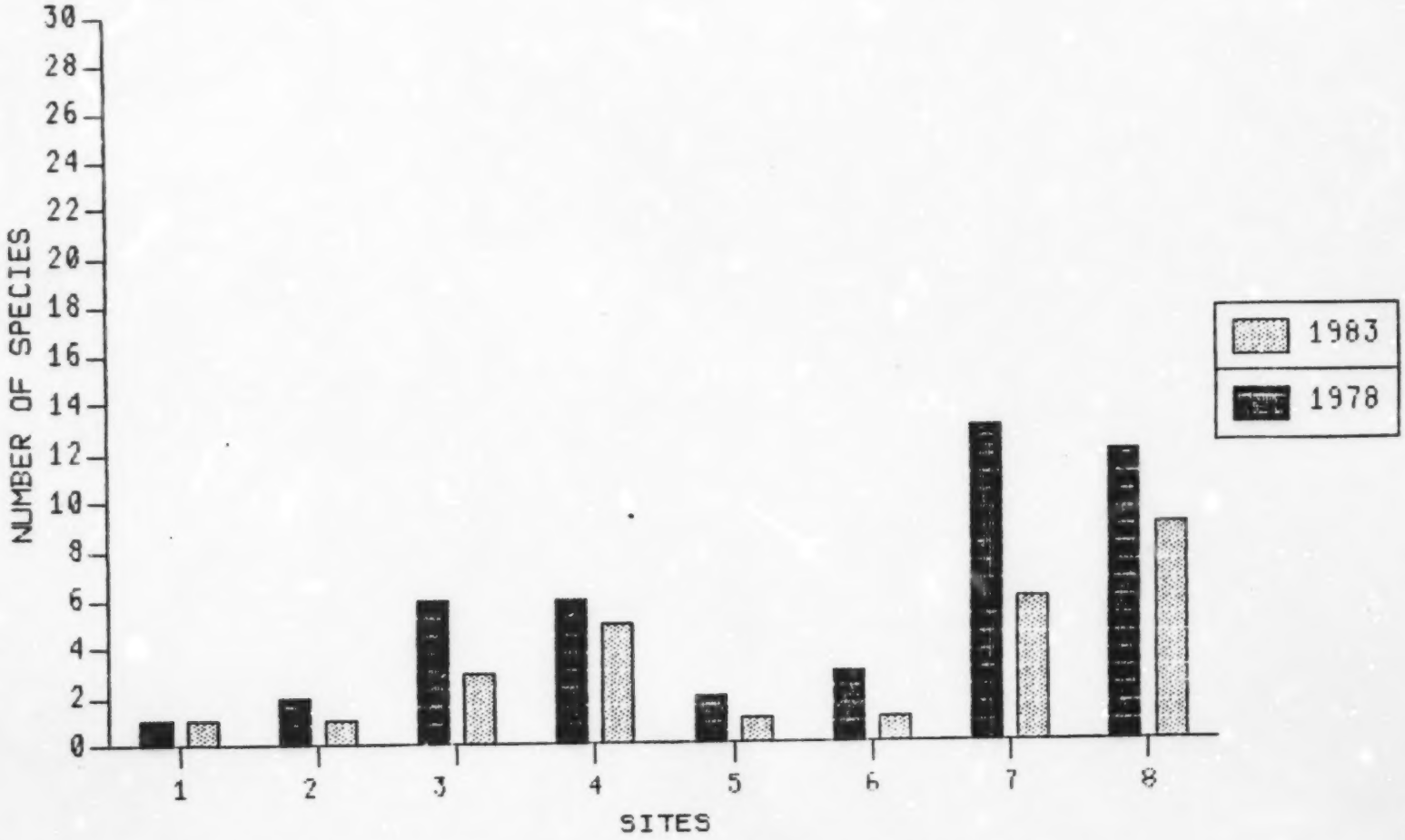

FIGURE 3: MOSS DISTRIBUTION IN FLIN FLON STUDY SITES

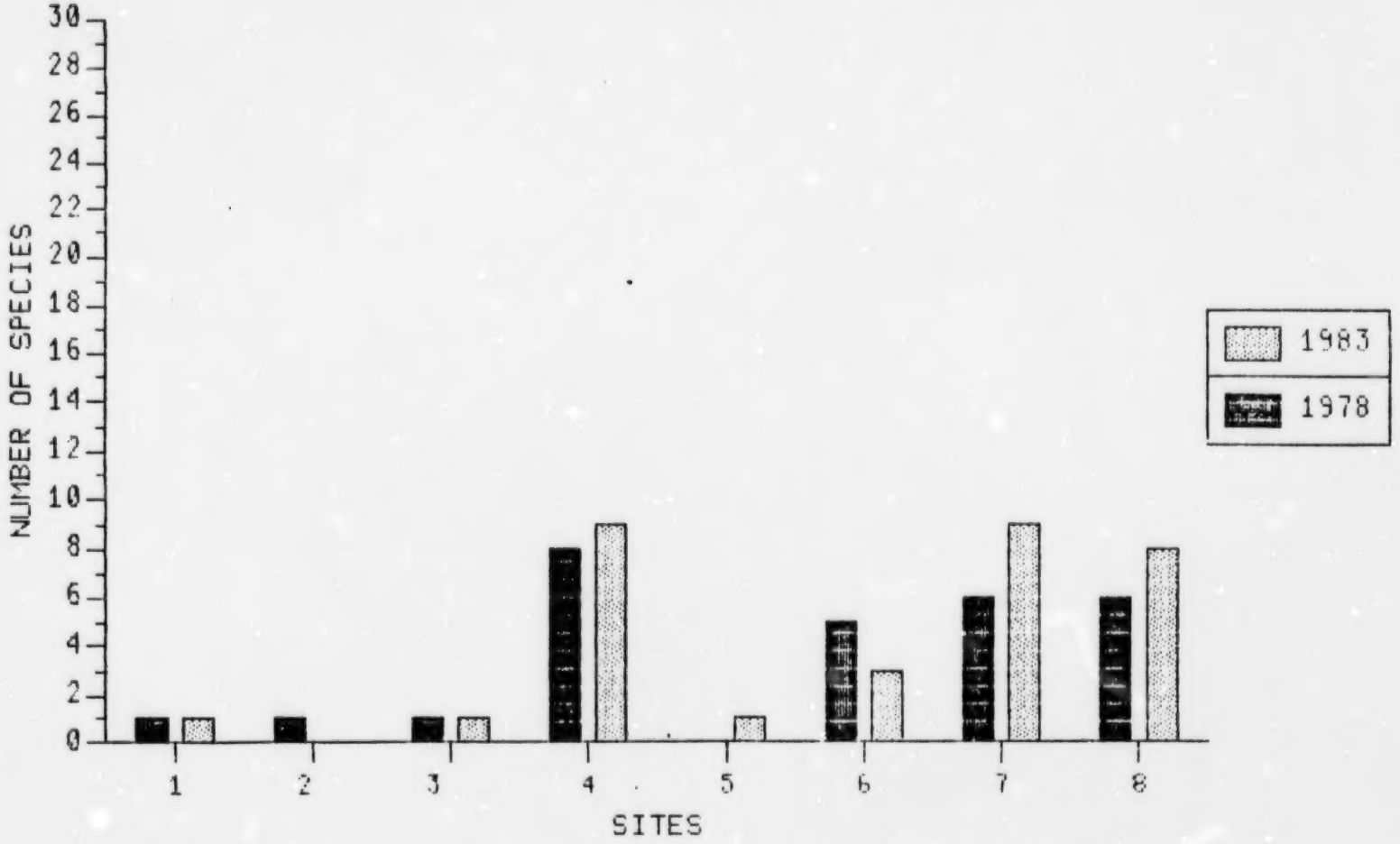

FIGURE 4: LICHEN DISTRIBUTION IN FLIN FLON STUDY SITES

As previously stated the inventory of moss and lichen cover was not detailed due to the high degree of specialization which would have been required. However, the cryptogams were evaluated in a consistent manner in both 1978 and 1983 and the data presented does provide some indication of species presence within the sampling network.

ASSOCIATION - UNDERSTORY

The study sites varied in distribution, in addition to the composition and abundance of understory species. In order to synthesize the large amount of community information the association tables were prepared based upon a frequency-cover index [(% frequency + % plant cover ÷ 2)]. Association tables can be used to detect subtle changes in stand composition and cover over time.

Relative changes in association value are presented in Table 4. A negative percentage change indicates a decrease in species diversity from 1978 to 1983, while a positive change indicates an increase in species diversity. Where a species was present in 1978 and absent in 1983 a value of -100 was assigned to the respective study sites, if it occurred for the first time in 1983, a value of 100 was entered in the table. In other words a -100 indicates a loss of a species and a +100 a new species.

Table 4: PERCENTAGE CHANGE IN ASSOCIATION VALUE OF UNDERSTORY SPECIES, 1978 to 1983.

No.	Species	Association Value* by Sample Plot 1	2	3	4	5	6	7	8
Shrubs									
1.	Alnus crispa	157.25	57.78	149.96		-45.51		100	
2.	Alnus rugosa					-100		100	
3.	Cornus stolonifera					-10.2			
4.	Viburnum trilobum	-100	-55.98	-45.74		2.84	2.02		-100
Tall Herb									
5.	Actaea rubra					-100			
6.	Aralia nudicaulis		23.91	23.62		18.13	0	-3.77	
7.	Epilobium angustifolium	3.92	52.05			3.92	-100		
8.	Hertensia paniculata	100	-100	-3.77	33.25	0			
9.	Rosa acicularis	-23.34	5.28	8.12	4.32	28.03	-3.75		4.16
10.	Shepherdia canadensis		-47.0						
Low Herb/Ground Shrubs									
11.	Arctostaphylos uva-ursi		3.39				-42.61		
12.	Calamagrostis canadensis						-100		
13.	Carex spp.		-100		-8.84	-5.36			
14.	Cornus canadensis	2.06	0.97	2.93	-100	-0.77	-17.40	2.94	-33.35
15.	Fragaria virginiana		94.12	-100	-9.37	-75.59			
16.	Galium triflorum	100.00				0	0		
17.	Geocaulon lividum		50.85	100	7.88	100	100		
18.	Goodyera repens							56.88	
19.	Grass (unidentified)	100.00	100.0		100	-12.20	100		
20.	Lathryus ochroleucus	0	-32.24				-1.98		
21.	Linnaea borealis	33.94	-9.32	-12.03	3.34	-1.65	-26.29	-4.66	0
22.	Maianthemum canadensis		100.0	100	100	199.88	-8.55	100	
23.	Mitella nuda	-8.27		-100	-15.8	-13.17			
24.	Monotropa uniflora				-1.98				
25.	Petasites palmatus			99.53	8.70	-4.10			
26.	Pyrola secunda	100	-0.94	100	100		100	100	
27.	Pyrola virens	-100	-100	3.9	30.58	-25.19	0	-50.96	
28.	Ribes glandulosum	100		12.82	100	100			
29.	Smilacina trifolia		-100	-100	-100	-100			
30.	Trientalis borealis			-13.23		401.78	-100		
31.	Vaccinium myrtilloides			100			-8.3		
32.	Vaccinium vitis-idaea				100				
33.	Viola pallens				-100				
34.	Viola renifolia			-25.56					
Pteridophytes									
35.	Equisetum hymale				-100				
36.	Equisetum scirpoides				33.01	24.35			
37.	Equisetum sylvaticum				69.47	-6.38			
38.	Lycopodium lucidulum								87.24
39.	Fragaria vesca			100	100	100			
40.	Juniperis communis		100						
41.	Prunus virginiana					100			
42.	Listera borealis								100

*Association value = $\frac{\% \text{ frequency} + \% \text{ cover}}{2}$

TABLE 5: SUMMARY OF UNDERSTORY CHARACTERISTICS, 1978 to 1983.

STUDY SITE	NO. OF SPECIES IN UNDERSTORY		% CHANGE IN ASSOCIATION VALUE 1978-83		
	1978	1983	% NEGATIVE	% POSITIVE	% NO CHANGE
1	10	13	29	64	7
2	19	18	45	55	0
3	16	19	40	60	0
4	19	21	36	64	0
5	28	26	52	41	7
6	18	20	59	26	15
7	8	10	33	67	0
8	7	8	33	50	17

Table 5 summarizes the total number of understory species for 1978 and 1983 together with the relative percentages of positive and negative change in association value over the 5 year period. During the 5 year period the data indicate a stable state at the control site 8. There was a negative change (loss of species diversity) in 33% of the understory species present, but that was offset by a positive change or a stable state in 67%.

These findings were consistent with those of the 2 sites located at the farthest points from the smelter on both transects. In site 7 the species distribution is similar to site 8 and the percent change in association value is identical to site 8. Site 4, the farthest site from the stack in the southeast transect, is found to have a close alignment of percent change in association value, 36% negative change and 64% positive. The number of species found at site 4 are more closely in line with those of the other sampled sites .

The other sites in the southeast transect, sites 1 to 3, show positive change in association value with the strongest gains in understory diversity being found at site 1. Site 1 was heavily affected by emissions in the past due to its close proximity to the smelter, 5.1 km. Past impacts on soil and vegetation were readily apparent in the field. It is likely that since the advent of the taller stack contaminant impingement at this site has been reduced and the vegetation may be responding with increased growth and diversity.

In the southern transect site 5, closest to the smelter (5.8 km), has the largest number of species present which would seem to indicate a productive state from the distribution aspect alone. However, the percent change in association value indicates a large negative change or decrease in species diversity. At site 6, a similar negative change was found. A strong negative change in association value suggests that a form of stress may be affecting the site.

The dynamics of a forest ecosystem dictate that change will occur and we can anticipate the loss and gain of species as a forest stand evolves. In establishing the sample sites there was no mechanism to predict the ecological state the forest communities were in at the time the study was initiated. The 1978 data served as a benchmark of the existing ecological state at each site. The 1983 monitoring provided a means of documenting change in the forest ecosystem. The comparison evaluation indicates the presence of a stress factor in certain sites.

The dispersal of air borne pollutants from the nonferrous metal smelter in the Flin Flon area has been well established (Blauel 1976, Franz[illegible] et al. 1979). The nature of the pollutant complex is well defined: SO_2, arsenic, copper, zinc, lead, cadmium. Deposition and accumulation of metal particulates has been documented within 35 km of the H.B.M.&S. smelter in vegetation and soils (Hogan and Wotton 1983). Snow surveys of the study site network have shown elevated metal particulate levels at those sites located closest to the smelter and in particular site 5 (Phillips et al 1983).

In a half century of smelting activities there has been a general decline in the forest community in the immediate vicinity of the Flin Flon smelter. Severe degradation is obvious in relic jack pine and spruce stands located a few kilometers to the south of the smelter complex. In these sites there is a depletion of species which are sensitive to atmospheric pollutants, similar forest decline has been observed in other regions of North America and is generally attributed to the combined effects of sulphur dioxide and heavy metal particulates (Hogan and Wotton 1980).

The study sites which showed the presence of a stress factor were located at 5.8 and 14.6 km from the smelter. It can be anticipated that the forest, to a degree, is reacting to the effects of atmospheric emissions from the smelter. Past and current information clearly indicates that emissions of air pollutants decrease expotentially with distance from the smelter and that elevated metal particulate levels have been recorded in soils, foliage and snow at these sites (Hogan and Wotton 1980, 1983).

At present the vegetation data base is variable and insufficent to identify and establish specific cause and effect relationships or to quantify long range impacts on the forest ecosystem.

CONCLUSIONS

A 5-year evaluation of study sites in the Flin Flon area has provided strong indication of stress occurring in the forest communities under study.

Study sites located in a transect south of the smelter stack were found to have consistently higher mortality among tree species present, a reduction in total living basal area in all sites and a decline in the shrub and understory layer of sites closest to the smelter.

In the site closest to the smelter in the southeast transect, the spruce mortality increased, however the total living basal area of trees as well as the understory vegetation increased over the five year period. This trend was not consistent with conditions at other sites to the southeast.

The moss and lichen species were increasingly abundant as distance from the smelter increased.

Further biological monitoring of the forest communities within the study network is required to quantify the impacts and to fully comprehend the documented changes in species diversity as well as to establish cause and effect relationships.

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APPENDIX A

INVENTORY DATA 1978

Table A-1: ASSOCIATION TABLE OF UNDERSTORY SPECIES, 1978.

No.	Species	Association Value* by Sample Plot 1	2	3	4	5	6	7	8
Shrubs									
1.	Alnus crispa	17.17	11.25	11.67		16.83			
2.	Alnus rugosa					10.00			
3.	Cornus stolonifera					40.42			
4.	Viburnum trilobum	9.00	20.83	36.25		29.59	8.42		8.42
Tall Herb									
5.	Actaea rubra					8.42			
6.	Aralia nudicaulis		36.05	45.17		48.33	16.83	8.75	
7.	Epilobium angustifolium	8.42	16.83			8.42	25.34		
8.	Hertensia paniculata		8.42	8.75	25.25	8.42			
9.	Rosa acicularis	26.09	25.17	26.59	25.25	34.34	17.58		8.42
10.	Shepherdia canadensis		16.83						
Low Herb/Ground Shrubs									
11.	Arctostaphylos uva-ursi		12.09				46.33		
12.	Calamagrostis canadensis						11.25		
13.	Carex spp.		34.00		50.92	23.33			
14.	Cornus canadensis	36.34	55.55	55.92	8.42	42.75	53.67	8.50	25.25
15.	Fragaria virginiana		8.67	41.34	37.34	34.50			
16.	Galium triflorum					8.42	8.50		
17.	Geocoulon lividum		25.25		8.50				
18.	Goodyera repens							27.25	
19.	Grass (unidentified)					9.59			
20.	Lathyrus ochroleucus	8.42	25.34				8.59		
21.	Linnaea borealis	45.17	65.80	65.84	27.92	35.25	41.84	19.75	8.42
22.	Maianthemum canadensis					8.42	29.25		
23.	Mitella nuda	20.08		8.42	10.00	51.92			
24.	Monotropa uniflora				8.59				
25.	Petasites palmatus			17.00	17.25	44.92			
26.	Pyrola secunda		8.50						
27.	Pyrola virens	16.92	16.83	53.34	26.42	33.75	8.42	17.17	
28.	Ribes glandulosum			8.50					
29.	Smilacina trifolia		46.00	34.75	8.42	8.42			
30.	Trientalis borealis			51.09		8.42	8.42		
31.	Vaccinium myrtilloides						10.00		
32.	Vaccinium vitis-idaea				8.50				
33.	Viola pallens				9.42				
34.	Viola renifolia			33.92					
Pteridophytes									
35.	Equisetum hyemale				8.42				
36.	Equisetum scirpoides				51.50	33.84			
37.	Equisetum sylvaticum				25.42	19.58			
38.	Lycopodium lucidulum								9.17

TABLE A-2: DISTRIBUTION OF UNDERSTORY, 1978

Species	SAMPLE PLOTS 1	2	3	4	5	6	7	8
Tree Regeneration								
Picea mariana	x			x	x	x	x	x
Picea glauca		x	x		x	x		
Abies balsamea						x		
Betula papyrifera			x		x	x	x	
Populus tremuloides				x	x	x		x
Populus balsamifera					x			
Shrubs								
Alnus crispa	x	x	x		x			
Alnus rugosa					x			
Cornus stolonifera					x			
Viburnum trilobum	x	x	x		x	x		x
Tall Herb								
Actaea rubra					x			
Aralia nudicaulis		x	x		x	x	x	
Epilobium angustifolium	x	x			x	x		
Hortensia paniculata		x	x	x	x			
Rosa acicularis	x	x	x	x	x	x		x
Shepherdia canadensis		x						
Low Herb/Ground Shrubs								
Arctostaphylos uva-ursi		x					x	
Calamagrostis canadensis						x		
Carex spp.		x		x	x			
Cornus canadensis	x	x	x	x	x	x	x	x
Fragaria virginiana		x	x	x	x			
Galium triflorum					x	x		
Geocaulon lividum		x		x				
Goodyera repens							x	
Grass (unidentified)					x			
Lathyrus ochroleucus	x	x				x		
Linnaea borealis	x	x	x	x	x	x	x	x
Melanthemum canadensis					x	x		
Mitella nuda	x		x	x	x			
Monotropa uniflora				x				
Petasites palmatus			x	x	x			
Pyrola secunda		x						
Pyrola virens	x	x	x	x	x	x	x	
Ribes glandulosum			x					
Smilacina trifolia		x	x	x	x			
Trientalis borealis			x		x	x		
Vaccinium myrtilloides						x		
Vaccinium vitis-idaea				x				
Viola pallens				x				
Viola renifolia		x						
Pteridophytes								
Equisetum hyemale				x				
Equisetum scirpoides				x	x			
Equisetum sylvaticum				x	x			
Lycopodium lucidulum								x
Total Species Present	10	19	12	19	28	18	8	7

TABLE A-3: MOSS, LIVERWORT AND LICHEN DISTRIBUTION, FLIN FLON, 1978

Species	SAMPLE PLOTS 1	2	3	4	5	6	7	8
Moss								
Aulacomnium palustre*							x	
Brachythecium salebrosum			x				x	x
Brotherella recurvans		x						x
Campylium hispidulum			x					
Campylium polygamum								x
Dicranum rugosum							x	x
Dicranum viride								x
Drepanacladus unicinatus							x	x
Eurhynchium pulchellum			x					
Hylocomium splendens				x			x	x
Hypnum crista-castrensis							x	x
Leptodictyum riparium					x			
Mnium spp.				x			x	
Plagiomnium cuspidatum			x				x	
Pleurozium schreberi				x		x	x	x
Pohlia nutans	x	x	x	x	x	x	x	x
Blepharostoma trichophyllum							x	x
Ptilidium pulcherrimum			x	x		x	x	x
Scapania irrigua							x	
Total Species Present	1	2	6	5	2	3	13	12
Lichen								
Alectoria americanna**								x
Cladonia deformis	x			x		x	x	
Cladonia mitis				x				x
Cladonia rangiferina				x		x	x	
Cetraria pinastri				x		x	x	
Evernia mesomorpha				x			x	x
Hypogymnia physodes				x		x	x	x
Peltigera aphthosa				x				
Stereocaulon tomentosum						x		
Usnea longissima								x
Unidentified		x	x	x			x	x
Total Species Present	1	1	1	8	0	5	6	6

* Nomenclature from: Conard 1956, How to Know the Mosses and Liverworts, and Crum 1973, Mosses of the Great Lakes Forest.

** Nomenclature from: Hale 1969, How to Know the Lichens

Table A-4: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 1, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	0.33	0.47	1.0	2.39	0.33	9.88
Viburnum trilobum	1.33	1.91	1.33	3.18	0.17	5.09
Tall Herb						
Epilobium angustifolium	0.17	0.24	0.17	0.41	0.17	5.09
Rosa acicularis	1.50	2.16	2.17	5.19	0.50	14.97
Low Herb/Ground Shrubs						
Cornus canadensis	9.33	13.43	6.0	14.34	0.67	20.06
Lathyrus ochroleucus	0.33	0.47	0.17	0.41	0.17	5.09
Linnaea borealis	40.83	58.77	23.67	56.57	0.67	20.06
Mitella nuda	14.33	20.62	6.83	16.32	0.33	9.88
Pyrola virens	1.33	1.91	0.50	1.20	0.33	9.88
TOTAL	69.48	100.0	41.84	100.0	3.34	100.0

Table A-5: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 2, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	0.83	0.65	5.83	6.99	0.17	2.17
Viburnun trilobum	2.67	2.09	8.33	9.99	0.33	4.21
Tall Herb						
Aralia nudicaulis	1.83	1.44	5.33	6.39	0.67	8.55
Epilobium angustifolium	0.67	0.53	0.33	0.40	0.33	4.21
Mertensia paniculata	0.33	0.26	0.17	0.20	0.17	2.17
Rosa acicularis	0.83	0.65	0.33	0.40	0.50	6.38
Shepherdia canadensis	0.67	0.53	0.33	0.40	0.33	4.21
Low Herb/Ground Shrubs						
Arctostaphylos uva-ursi	0.17	0.13	7.5	9.00	0.17	2.17
Carex spp.	2.0	1.57	1.33	1.60	0.67	8.55
Cornus canadensis	22.23	17.44	11.1	13.32	1.0	12.76
Fragaria virginiana	0.17	0.13	0.67	0.80	0.17	2.17
Geocaulon lividum	1.3	1.02	0.50	0.60	0.50	6.38
Lathyrus ochroleucus	1.0	0.78	0.67	0.80	0.50	6.38
Linnaea borealis	70.0	54.90	31.6	37.91	1.0	12.76
Pyrola secunda	1.0	0.78	0.33	0.40	0.17	2.17
Pyrola virens	0.5	0.39	0.33	0.40	0.33	4.21
Smilacina trifolia	21.3	16.71	8.67	10.40	0.83	10.59
TOTAL	127.5	100.0	83.35	100.0	7.84	100.0

Table A-6: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 3, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	0.33	0.23	6.67	7.17	0.17	1.88
Viburnum trilobum	3.83	2.63	5.83	6.27	0.67	7.43
Tall Herb						
Aralia nudicaulis	5.5	3.78	7.0	7.53	0.83	9.20
Mertensia paniculata	1.33	0.91	0.83	0.89	0.17	1.88
Rosa acicularis	3.50	2.41	3.17	3.41	0.50	5.54
Low Herb/Ground Shrubs						
Cornus canadensis	16.17	11.11	7.83	8.42	1.0	11.09
Fragaria virginiana	20.33	13.97	16.0	17.20	0.67	7.43
Linnaea borealis	60.0	41.24	31.67	34.05	1.0	11.09
Mitella nuda	0.33	0.23	0.17	0.18	0.17	1.88
Petasites palmatus	2.00	1.37	0.67	0.72	0.33	3.66
Pyrola virens	15.67	10.77	6.67	7.17	1.0	11.09
Ribes glandulosum	0.67	0.46	.33	0.35	0.17	1.88
Smilacina trifolia	7.00	4.81	2.83	3.04	0.67	7.43
Trientalis borealis	6.17	4.24	2.17	2.33	1.0	11.09
Viola renifolia	2.67	1.84	1.17	1.26	0.67	7.43
TOTAL	145.5	100.0	93.01	100.0	9.02	100.0

Table A-7: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 4, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Tall Herb						
Mertensia paniculata	0.83	0.85	0.50	0.63	0.5	7.86
Rosa acicularis	0.50	0.51	0.50	0.63	0.5	7.86
Low Herb/Ground Shrubs						
Carex spp.	26.5	27.09	18.5	23.22	0.83	13.05
Cornus canadensis	0.50	0.51	0.17	0.21	0.17	2.67
Fragaria virginiana	9.0	9.20	8.0	10.04	0.67	10.53
Geocaulon lividum	1.0	1.02	0.33	0.41	0.17	2.67
Linnaea borealis	15.67	16.02	5.83	7.32	0.50	7.86
Mitella nuda	9.33	9.54	3.33	4.18	0.17	2.67
Monotropa uniflora	1.17	1.20	0.50	0.63	0.17	2.67
Petasites palmatus	2.83	2.89	1.17	1.47	0.33	5.19
Pyrola virens	6.83	6.98	2.83	3.55	0.50	7.86
Smilacina trifolia	0.67	0.68	0.17	0.21	0.17	2.67
Vaccinium vitis-idaea	0.67	0.68	0.33	0.41	0.17	2.67
Viola pallens	0.33	0.34	0.17	0.21	0.17	2.67
Pteridophytes						
Equisetum hymale	0.17	0.17	0.17	0.21	0.17	2.67
Equisetum scirpoides	20.0	20.44	36.33	45.61	0.67	10.53
Equisetum sylvaticum	1.83	1.87	0.83	1.04	0.50	7.86
TOTAL	97.83	100.0	79.66	100.0	6.36	100.0

Table A-8: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 5, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	0.33	0.23	0.33	0.34	0.33	3.29
Alnus rugosa	0.67	0.46	3.33	3.45	0.17	1.69
Cornus stolonifera	1.83	1.25	14.17	14.68	0.67	6.68
Viburnum trilobum	4.0	2.73	9.17	9.50	0.50	4.99
Tall Herb						
Actaea rubra	0.17	0.12	.17	0.18	0.17	1.69
Aralia nudicaulis	8.5	5.81	13.33	13.81	0.83	8.28
Epilobium angustifolium	0.33	0.23	0.17	0.18	0.17	1.69
Mertensia paniculata	0.33	0.23	0.17	0.18	0.17	1.69
Rosa acicularis	2.33	1.59	2.0	2.07	0.67	6.68
Low Herb/Ground Shrubs						
Carex spp.	29.83	20.39	13.33	13.81	0.33	3.29
Cornus canadensis	4.67	3.19	2.17	2.25	0.83	8.28
Fragaria virginiana	3.00	2.05	2.33	2.41	0.67	6.68
Galium triflorum	0.17	0.12	0.17	0.18	0.17	1.69
Grass (unidentified)	5.33	3.64	2.5	2.59	0.17	1.69
Linnaea borealis	7.00	4.78	3.83	3.97	0.67	6.68
Maianthemum canadensis	0.17	0.12	0.17	0.18	0.17	1.69
Mitella nuda	61.5	42.03	20.5	21.24	0.83	8.28
Petasites palmatus	9.33	6.38	6.5	6.74	0.83	8.28
Pyrola virens	1.83	1.25	0.83	0.86	0.67	6.68
Smilacina trifolia	0.17	0.12	0.17	0.18	0.17	1.69
Trientalis borealis	0.67	0.46	0.17	0.18	0.17	1.69
Pteridophytes						
Equisetum scirpoides	4.17	2.85	1.0	1.04	.67	6.68
TOTAL	146.3	100.0	96.51	100.0	10.03	100.0

Table A-9: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 6, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Viburnum trilobum	0.17	0.19	0.17	0.31	0.17	3.18
Tall Herb						
Aralia nudicaulis	0.5	0.55	0.33	0.59	0.33	6.17
Epilobium angustifolium	1.17	1.29	0.67	1.21	0.50	9.35
Rosa acicularis	0.67	0.74	1.83	3.30	0.33	6.17
Low Herb/Ground Shrubs						
Arctostophylos uva-ursi	12.33	13.62	9.33	16.81	0.83	15.51
Calamagrostis canadensis	8.5	9.39	5.83	10.51	0.17	3.18
Cornus canadensis	13.83	15.28	7.33	13.21	1.0	18.69
Galium trifolium	1.17	1.29	0.33	0.59	0.17	3.18
Lathyrus ochroleucus	1.0	1.10	0.50	0.90	0.17	3.18
Linnaea borealis	34.17	37.75	17.0	30.64	0.67	12.52
Maianthemum canadensis	15.17	16.76	8.5	15.32	0.50	9.35
Pyrola virens	0.50	0.55	0.17	0.31	0.17	3.18
Trientalis borealis	0.50	0.55	0.17	0.31	0.17	3.18
Vaccinium myrtilloides	0.83	0.92	3.33	6.00	0.17	3.18
TOTAL	90.51	100.0	55.49	100.0	5.35	100.0

Table A-10: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 7, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Tall Herb						
Aralia nudicaulis	0.17	0.49	0.83	6.47	0.17	11.33
Low Herb/Ground Shrubs						
Cornus canadensis	1.0	2.90	0.33	2.57	0.17	11.33
Goodyera repens	13.17	38.17	4.5	35.07	0.50	33.33
Linnaea borealis	17.33	50.23	6.17	48.09	0.33	22.00
Pyrola virens	2.83	8.20	1.0	7.79	0.33	22.00
TOTAL	34.50	100.0	12.83	100.0	1.50	100.0

Table A-11: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 8, 1978.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Viburnum trilobum	0.17	2.83	0.17	6.34	0.17	14.41
Tall Herb						
Rosa acicularis	0.17	2.83	0.17	6.34	0.17	14.41
Low Herb/Ground Shrubs						
Cornus canadensis	0.83	13.81	0.50	18.66	0.50	42.37
Linnaea borealis	0.67	11.15	0.17	6.34	0.17	14.41
Pteridophytes						
Lycopodium lucidulum	4.17	69.38	1.67	62.31	0.17	14.41
TOTAL	6.01	100.0	2.68	100.0	1.18	100.0

APPENDIX B

INVENTORY DATA 1983

Table B-1: ASSOCIATION TABLE OF UNDERSTORY SPECIES, 1981.

No.	Species	Association Value* by Sample Plot 1	2	3	4	5	6	7	8
Shrubs									
1.	Alnus crispa	44.17	17.75	29.17		9.17		8.75	
2.	Alnus rugosa							8.75	
3.	Cornus stolonifera					36.25			
4.	Viburnum trilobum		9.17	19.67		30.43	8.59		
Tall Herb									
5.	Actaea rubra								
6.	Aralia nudicaulis		44.67	55.84		57.09	16.83	8.42	
7.	Epilobium angustifolium	8.75	25.59			8.75			
8.	Hertensia paniculata	9.17		8.42	33.67	8.42	16.92		
9.	Rosa acicularis	20.00	26.50	28.75	26.34	44.17			8.77
10.	Shepherdia canadensis		8.92						
Low Herb/Ground Shrubs									
11.	Arctostaphylos uva ursi		12.50				26.59		
12.	Calamagrostis canadensis								
13.	Carex spp.				46.42	22.08			
14.	Cornus canadensis	37.09	56.09	55.50		47.42	44.33	8.75	16.83
15.	Fragaria virginiana		16.83		33.84	8.42			
16.	Galium triflorum	8.42				8.42	8.50		
17.	Geocaulon lividum		38.09	8.50	9.17	16.83	8.42		
18.	Goodyera repens							42.75	
19.	Grass (unidentified)	17.58	34.67		8.50	8.42	11.67		
20.	Lathyrus ochroleucus	8.42	17.17				8.42		
21.	Linnaea borealis	29.84	59.67	57.92	28.75	34.67	30.84	18.83	8.42
22.	Maianthemum canadensis		44.92	43.67	9.17	25.25	26.75	8.42	
23.	Mitella nuda	18.42			8.42	45.08			
24.	Monotropa uniflora				8.42				
25.	Petasites palmatus			33.92	18.75	43.08			
26.	Pyrola secunda	2.19	8.42	16.83	8.42		16.83	8.75	
27.	Pyrola virens			55.42	34.50	25.25	8.42	8.42	
28.	Ribes glandulosum	8.42		9.59	8.42	16.83			
29.	Smilacina trifolia								
30.	Trientalis borealis			44.33		42.25			
31.	Vaccinium myrtilloides			8.50			9.17		
32.	Vaccinium vitis idaea				17.00				
33.	Viola pallens								
34.	Viola renifolia			25.25	8.42				
Pteridophytes									
35.	Equisetum hymale								
36.	Equisetum scirpoides				68.50	42.08			
37.	Equisetum sylvaticum				43.08	18.33			
38.	Lycopodium lucidulum								17.17
New Species 1982									
39.	Fragaria vesca			47.17	37.17	34.09			
40.	Juniperis communis		19.67						
41.	Prunus virginiana					8.50			
42.	Listera borealis								8.42

* Association value = $\frac{\text{\% frequency} + \text{\% cover}}{2}$

TABLE B-2: DISTRIBUTION OF UNDERSTORY, 1983

Species	SAMPLE PLOTS 1	2	3	4	5	6	7	8
Tree Regeneration								
Abies balsamea						x		x
Betula papyifera					x	x		
Picea glauca		x	x		x	x		
Picea mariana	x			x		x	x	x
Pinus banksiana						x		
Populus balsamifera		x						
Populus tremuloides			x	x		x	x	x
Shrubs								
Alnus crispa	x		x		x		x	
Alnus rugosa		x						
Cornus stolonifera					x			
Juniperus communis		x						
Prunus virginiana					x			
Viburnum trilobum		x	x		x	x		
Tall Herb								
Aralia nudicaulis		x	x		x	x	x	
Epilobium angustifolium	x	x			x			
Hertensia paniculata	x		x	x	x			
Rosa acicularis	x	x	x	x	x	x		x
Shepherdia canadensis		x						
Low Herb/Ground Shrub								
Arctostaphylos uva-ursi		x						
Calamagrostis canadensis						x		
Carex spp.				x	x			
Cornus canadensis	x	x	x		x	x	x	x
Fragaria vesca			x		x			
Fragaria virginiana		x		x	x			
Galium triflorum	x				x	x		
Geocaulon lividum		x	x	x	x	x		
Goodyera repens							x	
Grass (unidentified)	x	x		x	x	x		
Lathyrus ochroleucus	x	x				x		
Linnaea borealis	x	x	x	x	x	x	x	x
Maianthemum canadensis		x	x	x	x	x	x	
Mitella nuda	x			x	x			
Monotropa uniflora				x				
Listera borealis								x
Potasites palmatus			x	x	x			
Pyrola secunda	x	x	x	x		x	x	
Pyrola virens			x	x	x	x	x	
Ribes glandulosum	x		x	x	x			
Trientalis borealis			x		x			
Vaccinium myrtilloides			x			x		
Vaccinium vitis-idaea				x				
Viola renifolia			x	x				
Pteridophytes								
Equisetum scirpoides				x	x			
Equisetum sylvaticum				x	x			
Lycopodium lucidulum				x				x
Total Species Present	13	18	19	21	26	20	10	8

TABLE B-3: DISTRIBUTION OF MOSS, LIVERWORT AND LICHEN, 1983

Species	SAMPLE PLOTS 1	2	3	4	5	6	7	8
Moss								
Aulocomnium palustre				x				
Dicranum fuscensens				x				
Dicranum rugosum							x	x
Dicranum spp.								x
Hylocomium splendens				x			x	x
Mnium punctatum							x	
Moss (unidenfitied)			x					x
Pleurozium schreberi				x			x	x
Pohlia nutans	x	x	x	x	x	x	x	x
Ptilidium crista-castrensis							x	x
Ptilidium ciliare			x	x				x
Umbellicaria								x
Total Species Present	1	1	3	6	1	1	6	9
Lichen								
Alectoria				x			x	x
Cetraria halei				x			x	x
Cetraria pinustre				x			x	x
Cetraria spp.						x		
Cladina crista-castrensis				x			x	
Cladina rangiferina				x		x	x	x
Cladina spp.	x		x	x		x	x	x
Evernia mesomorpha				x			x	x
Hypogymnia							x	
Parmelia sulcata				x			x	x
Peltigera aphthosa					x			
Usnea longissima				x				x
Total Species Present	1	0	1	9	1	3	9	8

Table B-4: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 1, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	2.83	5.01	21.67	40.11	0.67	17.40
Tall Herb						
Epilobium angustifolium	0.33	0.58	0.83	1.54	0.17	4.42
Rosa acicularis	3.17	5.61	6.67	12.35	0.33	8.57
Low Herb						
Cornus canadensis	17.33	30.67	7.50	13.88	0.67	17.40
Galium triflorum	0.33	0.58	0.17	0.31	0.17	4.42
Grass (unidentified)	2.00	3.54	1.83	3.39	0.33	8.57
Lathyrus ochroleucus	0.17	0.30	0.17	0.31	0.17	4.42
Linnaea borealis	16.67	29.50	9.67	17.90	0.50	12.99
Mertensia paniculata	2.0	3.54	1.67	3.09	0.17	4.42
Mitella nuda	11.17	19.77	3.50	6.48	0.33	8.57
Pyrola secunda	0.17	0.30	0.17	0.31	0.17	4.42
Ribes glandulosum	0.33	0.58	0.17	0.31	0.17	4.42
TOTAL	56.50	100.0	54.02	100.0	3.85	100.0

Table B-5: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 2, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	0.67	0.44	2.17	2.68	0.33	4.13
Juniperis communis	0.17	0.11	6.00	7.42	0.33	4.13
Viburnum trilobum	3.50	2.29	1.67	2.07	0.17	2.13
Tall Herb						
Aralia nudicaulis	3.33	2.18	6.0	7.42	0.83	10.38
Epilobium angustifolium	0.67	0.44	1.17	1.45	0.50	6.25
Rosa acicularis	1.50	0.98	3.0	3.71	0.50	6.25
Shepherdia canadensis	0.33	0.22	0.83	1.03	0.17	2.13
Low Herb/Ground Shrubs						
Arctostaphylos uva-ursi	10.5	6.86	8.33	10.30	0.17	2.13
Cornus canadensis	26.17	17.10	12.17	15.05	1.00	12.50
Fragaria virginiana	0.33	0.22	0.33	0.41	0.33	4.13
Geocaulon lividum	18.83	12.31	9.50	11.75	0.67	8.38
Grass (unidentified)	5.67	3.71	2.67	3.30	0.67	8.38
Lathyrus ochroleucus	2.0	1.31	1.0	1.24	0.33	4.13
Linnaea borealis	58.0	37.91	19.33	23.91	1.0	12.50
Maianthemum canadensis	20.67	13.51	6.5	8.04	0.83	10.38
Pyrola secunda	0.67	0.44	0.17	0.21	0.17	2.13
TOTAL	153.01	100.0	80.84	100.0	8.00	100.0

Table B-6: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 3, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	3.67	2.43	25.0	22.03	0.33	3.36
Viburnum trilobum	4.00	2.65	6.0	5.29	0.33	3.36
Tall Herb						
Aralia nudicaulis	7.83	5.18	11.67	10.28	1.0	10.17
Mertensia paniculata	0.33	0.22	0.17	0.15	0.17	1.73
Rosc acicularis	4.83	3.20	7.50	6.61	0.50	5.09
Low Herb						
Cornus canadensis	18.83	12.46	11.0	9.69	1.0	10.17
Fragaria vesca	14.83	9.81	11.0	9.69	0.83	8.44
Geocaulon lividum	1.00	0.66	0.33	0.29	0.17	1.73
Linnaea borealis	50.33	33.30	15.83	13.95	1.00	10.17
Maianthemum canadensis	8.50	5.62	4.00	3.52	0.83	8.44
Petasites palmatus	2.33	1.54	1.17	1.03	0.67	6.82
Pyrola secunda	0.50	0.33	0.33	0.29	0.33	3.36
Pyrola virens	22.00	14.56	10.83	9.54	1.00	10.17
Ribes glandulosum	1.50	0.99	2.50	2.20	0.17	1.73
Trientalis borealis	9.67	6.40	5.33	4.70	0.83	8.44
Vaccinium myrtilloides	0.33	0.22	0.33	0.29	0.17	1.73
Viola renifolia	0.66	0.44	0.50	0.44	0.50	5.09
TOTAL	151.14	100.0	113.49	100.0	9.83	100.0

Table B-7: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 4, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Tall Herb						
Mertensia paniculata	1.83	1.40	0.67	0.83	0.67	8.01
Rosa acicularis	0.67	0.51	2.67	3.32	0.50	5.98
Low Herb						
Carex spp.	20.0	15.32	9.50	11.80	0.83	9.93
Fragaria vesca	12.7	9.73	7.67	9.52	0.67	8.01
Fragaria virginiana	2.17	1.66	1.0	1.24	0.67	8.01
Geocaulon lividum	2.17	1.66	1.67	2.07	0.17	2.03
Grass (unidentified)	0.67	0.51	0.33	0.41	0.17	2.03
Linnaea borealis	18.83	14.43	7.50	9.31	0.50	5.98
Maianthemum canadensis	1.83	1.40	1.67	2.07	0.17	2.03
Mitella nuda	0.83	0.64	0.17	0.21	0.17	2.03
Monotropa uniflora	0.83	0.64	0.17	0.21	0.17	2.03
Petasites palmatus	4.83	3.70	4.17	5.18	0.33	3.95
Pyrola secunda	0.33	0.25	0.17	0.21	0.17	2.03
Pyrola virens	5.67	4.34	2.33	2.89	0.67	8.01
Ribes glandulosum	0.17	0.13	0.17	0.21	0.17	2.03
Vaccinium vitis-idaea	2.17	1.66	0.67	0.83	0.33	3.95
Viola renifolia	0.33	0.25	0.17	0.21	0.17	2.03
Pteridophytes						
Equisetum scirpoides	52.83	40.47	37.0	45.95	1.0	11.96
Equisetum sylvaticum	1.67	1.28	2.83	3.51	0.83	9.93
TOTAL	130.53	100.0	80.53	100.0	8.36	100.0

Table B-8: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 5, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	0.67	0.47	1.67	2.30	0.17	1.42
Cornus stolonifera	1.83	1.28	5.83	8.04	0.67	5.58
Prunus virginiana	0.17	0.12	0.33	0.46	0.17	1.42
Viburnum trilobum	4.00	2.79	10.85	14.96	0.50	4.17
Tall Herb						
Aralia nudicaulis	17.67	12.34	14.17	19.54	1.00	8.33
Epilobium angustifolium	0.50	0.35	0.83	1.14	0.17	1.42
Mertensia paniculata	0.17	0.12	0.17	0.23	0.17	1.42
Rosa acicularis	1.83	1.28	5.00	6.90	0.83	6.92
Low Herb						
Carex spp.	34.00	23.75	10.83	14.94	0.33	2.75
Cornus canadensis	4.50	3.14	1.50	2.07	0.83	6.92
Fragaria vesca	2.33	1.63	1.50	2.07	0.67	5.58
Fragaria virginiana	0.33	0.23	0.17	0.23	0.17	1.42
Galium triflorum	0.33	0.23	0.17	0.23	0.17	1.42
Geocaulon lividum	1.50	1.05	0.33	0.46	0.33	2.75
Grass (unidentified)	2.50	1.75	0.17	0.23	0.17	1.42
Linnaea borealis	11.83	8.26	2.67	3.68	0.67	5.58
Maianthemum canadensis	1.17	0.82	0.50	0.69	0.50	4.17
Mitella nuda	38.67	27.01	6.83	9.42	0.83	6.92
Petasites palmatus	6.67	4.66	2.83	3.90	0.83	6.92
Pyrola virens	0.50	0.35	0.50	0.69	0.50	4.17
Ribes glandulosum	0.50	0.35	0.33	0.46	0.33	2.75
Trientalis borealis	4.17	2.91	1.17	1.61	0.83	6.92
Pteridophytes						
Equisetum scirpoides	3.17	2.21	0.83	1.14	0.83	6.92
Equisetum sylvaticum	4.17	2.91	3.33	4.59	0.33	2.75
TOTAL	143.18	100.0	72.51	100.0	12.00	100.0

Table B-9: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 6, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Viburnum trilobum	0.33	0.44	0.50	1.45	0.17	3.74
Tall Herb						
Aralia nudicaulis	0.33	0.44	0.33	0.96	0.33	7.25
Rosa acicularis	1.00	1.32	0.50	1.45	0.33	7.25
Low Herb						
Arctostaphylos uva-ursi	7.33	9.69	3.17	9.19	0.50	10.99
Cornus canadensis	15.0	19.83	5.33	15.44	0.83	19.12
Galium triflorum	1.00	1.32	0.33	0.96	0.17	3.74
Geocaulon lividum	0.33	0.44	0.17	0.49	0.17	3.74
Grass (unidentified)	10.33	13.65	6.67	19.33	0.17	3.74
Lathyrus ochroleucus	0.50	0.66	0.17	0.49	0.17	3.74
Linnaea borealis	25.33	33.48	11.67	33.82	0.50	10.99
Maianthemum canadensis	9.67	12.78	3.50	10.14	0.50	10.99
Pyrola secunda	1.67	2.21	0.33	0.96	0.33	7.25
Pyrola virens	0.33	0.44	0.17	0.49	1.17	3.74
Vaccinium myrtilloides	2.50	3.30	1.67	4.84	0.17	3.74
TOTAL	75.65	100.0	34.51	100.0	4.55	100.0

Table B-10: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 7, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Shrubs						
Alnus crispa	0.50	2.10	0.83	8.03	0.17	7.23
Alnus rugosa	0.33	1.38	0.83	8.03	0.17	7.23
Tall Herb						
Aralia nudicaulis	0.17	0.71	0.17	1.65	0.17	7.23
Low Herb						
Cornus canadensis	1.17	4.91	0.83	8.03	0.17	7.23
Goodyera repens	7.50	31.46	2.17	21.01	0.83	35.32
Linnaea borealis	11.67	48.95	4.33	41.92	0.33	14.04
Maianthemum canadensis	0.17	0.71	0.17	1.65	0.17	7.23
Pyrola secunda	2.0	8.39	0.83	8.03	0.17	7.23
Pyrola virens	0.33	1.38	0.17	1.65	0.17	7.23
TOTAL	23.84	100.0	10.33	100.0	2.35	100.0

Table B-11: COMPOSITION AND ABUNDANCE OF UNDERSTORY SPECIES, PLOT 8, 1983.

Species	Density	Relative Density (%)	Dominance	Relative Dominance (%)	Frequency	Relative Frequency (%)
Tall Herb						
Rosa acicularis	0.33	15.21	0.87	34.25	0.17	14.53
Short Herb						
Cornus canadensis	0.50	23.04	0.33	12.99	0.33	28.21
Linnaea borealis	0.17	7.83	0.17	6.69	0.17	14.53
Orchid spp.	0.17	7.83	0.17	6.69	0.17	14.53
Pteridophytes						
Lycopodium lucidulum	1.0	46.08	1.0	39.37	0.33	28.21
TOTAL	2.17	100.0	2.54	100.0	1.17	100.0